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(71) Applicant: CONSOLIDATED ENGINEERING COMPANY, INC. [US/US]; 1971 McCollum Parkway, Kennesaw, GA 30144-3651 (US).

(72) Inventors: CRAFTON, Scott, P.; 899 Old Mountain Road, Marietta, GA 30064 (US). CRAFTON, Paul, M.; 1194 Valley Reserve Drive, Kennesaw, GA 30144 (US). KNOBLOCH, Volker, R.; 515 Town Lake Hills North, Woodstock, GA 30189 (US). LEWIS, James, L., Jr.; 3760 Stonewall Drive, Kennesaw, GA 30152 (US). FRENCH, Ian; 2716 Spindle Top Lane, Kennesaw, GA 30144 (US).

(74) Agents: ISAF, Louis, T. et al.; Womble Carlyle Sandridge & Rice, P.O. Box 720601, Atlanta, GA 30358-2601 (US).



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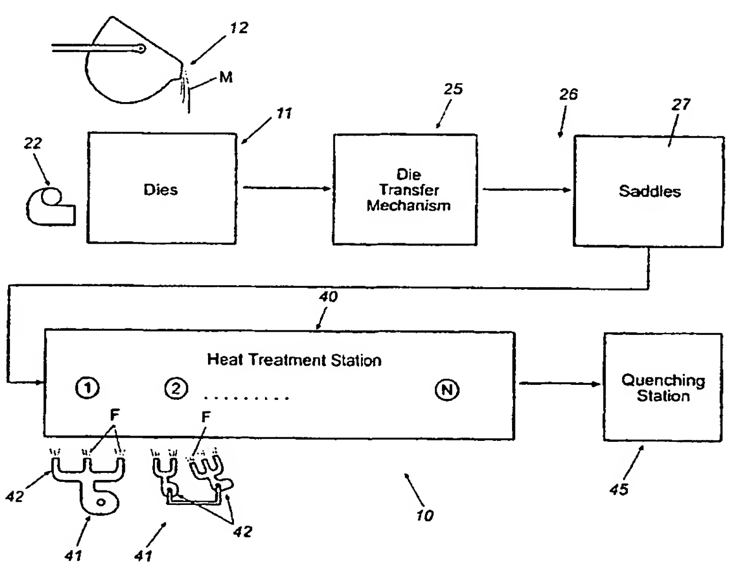



(57) Abstract: A system and method for heat treating castings (13, 53) and removal cores (54) therefrom. The castings (13, 53) are initially located in indexed positions with their x, y, and z coordinates known. The castings (13, 53) are passed through a series of nozzle stations (41, 63) each having a series of nozzles (42, 64, 64') mounted in present positions corresponding to the known indexed positions of the castings passing through the nozzle stations (41, 63). The nozzle (42, 64, 64') apply heated fluids to the castings (13, 53) for heat treating the castings (13, 53) and dislodging the sand cores (54) for removal from the castings (13, 53).


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# HEAT TREATMENT AND SAND REMOVAL FOR CASTINGS

## CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of United States Provisional Application Serial No. 60/146,390, filed July 29, 1999, United States Provisional Application Serial No. 60/150,901, filed August 26, 1999, and United States Provisional Application Serial No. 60/202,740, filed May 10, 2000.

## TECHNICAL FIELD

This invention generally relates to metallurgical casting processes, and more specifically to a method and apparatus for removal of a sand core from a casting and the heat treatment of the casting.

## BACKGROUND OF THE INVENTION

A traditional casting process for forming metal castings employs, for example, a cast iron flask-type mold or sand mold, also known as a die, having the exterior features of a desired casting, such as a cylinder head, formed on its interior surfaces. A sand core comprised of sand and a suitable binder material and defining the interior features of the casting is placed within the die. Sand cores generally are used to produce contours and interior features within the metal castings, and the removal and reclaiming of the sand materials of the cores from the castings after the casting process is completed is a necessity. Depending upon the application, the binder for the sand core and/or sand mold, if used, may comprise a phenolic resin binder, a phenolic urethane "cold box" binder, or other suitable organic binder material. The die is then filled with a molten metallic alloy. When the alloy has solidified, the casting generally is removed from the die and is then moved to a treatment furnace(s) for heat-treating, reclamation of the sand from the sand cores, and aging. Heat treating and aging are processes that condition metallic alloys so that they will be provided with different physical characteristics suited for different applications.

In accordance with some of the prior art, once the casting is formed, several distinctly different steps generally must be carried out in order to heat treat the metal casting and reclaim sufficiently pure sand from the sand core. A first step separates portions of sand core from the casting. The sand core is typically separated from the casting by one or a combination of means. For example, sand may be chiseled away from the casting or the casting may be physically shaken or vibrated to break-up the sand core and remove the sand. Once the sand is removed from the casting, heat treating and aging of the casting generally are carried out in subsequent steps. The casting is typically heat treated if it is desirable to strengthen or harden the casting. An additional step consists of purifying the sand that was separated from the casting. The purification process is typically carried out by one or a combination of means. These may include burning the binder that coats the sand, abrading the sand, and passing portions of the sand through screens. Therefore, portions of sand may be re-subjected to reclaiming processes until sufficiently pure sand is reclaimed.

There is, therefore, a desire in the industry to enhance the process of heat treating castings and reclaiming sand core materials therefrom such that a continuing need exists for a more efficient method, and associated apparatus, that allow for more efficient heat treatment, sand core removal, and reclamation of sufficiently pure sand from the sand core.

## SUMMARY OF THE INVENTION

Briefly described, the present invention comprises a system and method for heat treating castings, such as for use in a metallurgical plant, and for

removing the sand cores used during the casting processes. The present invention encompasses multiple embodiments for efficiently removing and reclaiming the sand of sand cores using high pressure fluid media, and for in-die heat treatment of the castings.

In one embodiment of the present invention for sand core removal and heat treatment of castings, a molten metal is poured into dies that are typically preheated to maintain the temperature of the metal close to a heat treatment temperature as the castings are formed in the dies. The castings are then removed from their dies and are each placed in a pre-defined position on a saddle that has known x, y and z axes and coordinates. Each saddle generally is configured to receive a casting in a fixed orientation or position with the x, y, and z coordinates of the casting located in a known, indexed position or orientation so that the core apertures of the castings formed by the sand cores are oriented or aligned in known, indexed positions. The saddles further can include locating devices to guide and help maintain the castings in their desired, known indexed position.

Each saddle, with a casting positioned therein, is moved through a heat treatment furnace or chamber of a heat treatment station for heat treatment and core removal, and also potentially the reclamation of the sand cores. While passing through the heat treatment station for heat treatment, a series of nozzles with x, y and z coordinates that are fixed or set in alignment with the position of castings direct flows of high pressure, heated fluid media, such as air, water or thermal oil, onto and into the castings. The fluid flows tend to dislodge and aid in removal of the sand of the sand cores from the internal cavities of the castings as

the sand cores are broken down in the heat treatment station. Typically, the nozzles are arranged in a series of nozzle stations positioned sequentially through the heat treatment chamber, with the nozzles of each nozzle station oriented in a pre-defined arrangement corresponding to the known positions of the core apertures of the castings, and each nozzle assembly can be controlled remotely through a control system or station.

In another embodiment of the invention, the castings can be left in their dies for "in-die" heat treatment of the castings. The dies typically are pre-heated before the molten metal of the castings is poured into them to maintain the metal close to a heat treatment temperature for the castings, so as to partially heat treat the castings inside the dies while the castings solidify. Thereafter, the dies, with their castings therein, typically are located or placed in indexed orientations or positions with their x, y and z coordinates known for heat treatment of the castings therein and removal of the sand cores.

For heat treatment and the removal and reclamation of the sand cores of the castings, the dies and castings generally are passed through a heat treatment furnace of a heat treatment station. The heat treatment station further includes a plurality of nozzle stations each having a series of nozzles oriented or positioned in a pre-defined manner corresponding to the known positions of the dies and castings for applying high pressure fluids thereto. The nozzle stations also can include robotically operated nozzles that move along a pre-defined path around the dies, into various application positions corresponding to the positions or orientations of die access openings or apertures in the dies for access to the

castings for dislodging the sand cores from the castings. Alternately, the heat treatment station can also include alternative energy sources, such as inductive or radiant energy sources, or an oxygen chamber, for supplying energy to the dies or mold packs to raise their temperature for heat treating the castings therewithin. Thereafter, the castings are removed from their dies and passed through subsequent core removal stations or processes to further remove and potentially reclaim the sand cores from the castings.

In a further embodiment, the dies are pre-heated to a pre-defined temperature. Thereafter, as molten metal is poured into the dies, the dies continue to be heated to heat treat castings as they are solidified without removing the castings from the dies. The dies can then be transferred to a quenching station for quenching of the castings and removal of the sand cores therefrom. In this embodiment, the dies generally are maintained in a known, fixed position or orientation at or adjacent to the pouring station. The dies are heated by the application of heated fluids from a series of nozzles positioned about the dies, typically in alignment with die access openings thereof. The nozzles further are subsequently moved about the dies between a series of nozzle positions set according to the position or orientation of the dies, for heating the dies to heat treat the castings within the dies.

Various objects, features, and advantages of the present invention will become apparent upon reading and understanding this specification, taken in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic illustration of a first embodiment of the present invention.

Fig. 2 is a side elevational view illustrating introduction of molten metal into a die.

Fig. 3 is a perspective view illustrating the positioning of a casting within a saddle.

Fig. 4 is a schematic illustration of a further embodiment of the present invention for in-die heat treating with sand core removal process.

Figs. 5A-5B are side elevational views illustrating movement of the air nozzles to various application positions about a die for in-die heat treatment.

Fig. 6 is a side elevational view schematically illustrating an alternative embodiment of a heating chamber for in-die heat treatment of castings.

Fig. 7 is a side elevational view schematically illustrating another alternative embodiment of a heating chamber for in-die heat treatment of castings.

Figs. 8A – 8B are side elevational views schematically illustrating further alternative embodiments of heating chambers for in-die heat treatment of castings.

## DETAILED DESCRIPTION OF THE INVENTION

Referring now in greater detail to the drawings in which like numerals refer to like parts throughout the several views, Fig. 1 generally illustrates a metallurgical casting process 10. Casting processes are well known to those

skilled in the art, and a traditional casting process will be described only briefly for reference purposes.

As illustrated in Figs 1 and 2, according to the present invention, a molten metal or metallic alloy M is poured into a die 11 at a pouring or casting station 12 for forming a casting 13 (Fig. 3) such a cylinder head or an automobile engine block. Typically, casting cores are received or placed so as to create hollow cavities and/or casting details or core prints within the castings being formed within each die. Each of the dies 11 typically is a flask type mold and can be formed from a metal such as cast iron or other materials, as is known in the art, having a clam-shell style design for ease of opening and removal of the castings therefrom. The dies can also be a green sand type molds formed from a sand material mixed with a binder such as a phenolic resin or other suitable organic binder material as is known the art. Similarly, the casting cores typically comprise sand cores formed form a sand material and a suitable binder such as a phenolic resin, phenolic urethane "cold box" binder, or other suitable organic binder material as is conventionally known.

As Fig. 3 illustrates, each die 11 generally includes a series of sidewalls 14, a top or upper wall 16, and lower wall or bottom 17, which define an internal cavity 18 within which the molten metal M is received. The internal cavity 18 generally is formed with a relief pattern for forming the internal features of the castings 13 to be formed within the dies so as to define the shape or configuration of the finished castings. A pour opening 19 generally is formed in the upper wall or top 16 of each die and communicates with internal cavity 18 to enable the

molten metal M to be poured or otherwise introduced into the die as indicated in Figs. 1 and 2. The resultant casting has the features of the internal cavity of the die, with additional core apertures or access openings 21 also being formed therein where the sand cores are positioned within the dies.

A heating element, such as a heated air blower or other suitable gas or electric fired heater mechanism 22 also generally is provided adjacent the pouring station 12 for preheating the dies 11. Alternatively, the dies can be provided with heating sources or elements for heating the dies. For example, the dies can include cavities adjacent the casting in which a heated medium such as a thermal oil is received for heating the dies. Typically, the dies are preheated to a desired temperature depending upon the metal or alloy used to form the casting. For example, for aluminum, the dies would be preheated to a range of approximately 400 – 600°C. The varying preheating temperatures required for preheating the various metallic alloys and other metals for forming castings are well known to those skilled in the art and can include a wide range of temperatures above and below 400 – 600°C. The pre-heating of the dies helps maintain the metal of the castings at or near a heat treatment temperature so as to minimize heat loss as the molten metal is poured and solidifies in the dies and the dies thereafter are transferred to a subsequent processing station for heat treatment of the castings.

As indicated in Fig. 1, once the molten metal or metallic alloy has been poured into the die and has at least partially solidified into a casting, the die and casting are removed from the pouring station 12 by a die transfer mechanism 25, and are transferred to a loading station 26. The die transfer mechanism can

include a die transfer robot (not shown), winch or other type of conventionally known transfer mechanism for moving the dies from the pouring station to the loading station. In a first embodiment of the invention, after the molten metal M has solidified within the die so as to form the casting, the casting 13 (Fig. 3) is removed from its die 11 at the loading station 26 (Fig. 1), such as by a robotic arm or similar mechanism, and is placed within a saddle 27 in a predefined, indexed position with its x, y, and z coordinates known. As a result, the core apertures 21 (Fig. 3) of the castings likewise are oriented or aligned in known positions for removal of the sand cores from the castings.

As Fig. 3 illustrates, each saddle generally is a basket or carrier typically formed from a metal material and having a base 28 and a series of side walls 29 so as to define an open casting chamber or receptacle 31 in which the castings 13 are received with the core apertures or access openings thereof exposed. The castings are generally fixed in their known indexed or registered orientation or position when placed within the receptacle 31 of their saddle 27. In addition, as indicated in Fig. 3, the saddles 27 can further include locating devices 32 mounted to the base and/or walls 28 and 29 of each saddle for guiding and maintaining the castings into their desired, indexed positions within the saddles 27. The locating devices can include guide pins 33, such as shown in Fig. 3, or can include notches or grooves, such as indicated by dashed lines 34 in Fig. 3 or other, similar devices for guiding or directing the castings into a desired indexed position or orientation. Typically, the guide pins 33 will be formed from a metal material such as cast iron or similar material having a high heat resistance, and are mounted to the base

or any of the sidewalls of the saddle. Corresponding locator or guide openings 36 (shown in dashed lines) generally are formed in the casting during the casting process, such as by the use of guide pins mounted to the bottom or side walls of the dies, or through the use of degradable sand core-type materials. As the castings are placed within their saddles, the guide pins are received within the corresponding guide openings of the castings so as to locate and maintain the castings in their desired, indexed positions having known, defined x, y and z coordinates, with the positions of the core access openings of the castings likewise oriented or aligned at known positions to enable more efficient and direct application of heat to the sand cores within the castings to enhance the dislodging and removal of the sand material for reclamation.

In addition, in certain applications, the dies may include a steel or iron "chill" or insert having various design features of the casting imparted thereon for improved grain structure of the casting. These chills can be either removed after pouring or can be left with and remain part of the casting upon solidification of the molten metal of the casting. The chills, if left in the casting, also can be used as locating devices to enable the castings to be located within their saddles in their desired alignment or position. The features or detail left by the removal of the chill can also act as a locating point for engagement of a guide pin or other locating device within the saddle so as to hold each casting in its desired, indexed position.

As indicated in Fig. 1, after each casting 11 has been loaded in its saddle with the x, y and z coordinates of its position or orientation known, each castings

is then moved in the saddles into a heat treatment station 40 for heat treatment, core removal and sand reclamation if desired. The saddles are generally conveyed or moved through the heat treatment station on a conveyor or rails so that the castings are maintained in their known indexed positions as they are moved through the heat treatment station. The heat treatment station 40 generally includes a heat treatment furnace, typically a gas fired furnace, having a series of treatment zones or chambers for heat treating each casting and removal and reclamation of the sand material of the sand cores. The number of treatment zones can be divided into as many or as few number of zones as the individual applications may require to heat treat and remove the sand cores therefrom, and each casting typically is kept inside its die until a saddle is available to move it through a heat treatment station. It is further possible to additionally age the castings within the heat treatment station 40 if so desired.

Examples of a heat treatment furnace or system in which heat treatment of castings is carried out in conjunction with the removal of the sand cores from the castings, and potentially the reclamation of the sand from the sand cores of the castings as well, are illustrated in U.S. Pat. Nos. 5,294,094; 5,565,046; and 5,738,162, the disclosures of which are incorporated herein by reference. A further example of a heat treatment furnace for the heat treatment of metal castings and in-furnace and sand core removal and sand reclamation that can be utilized with the present invention is illustrated in U.S. Patent Application serial no. 09/313,111, filed May 17, 1999, the disclosure of which is likewise incorporated herein by reference.

As indicated in Fig. 1, the heat treatment station 40 includes a series of nozzle stations 41 positioned at spaced intervals along the length of the heat treatment station to enhance the heat treatment and sand core removal from the castings. The number of nozzle stations positioned along the heat treatment station can vary as needed, depending upon the core print or design of the casting. Each of the nozzle stations or assemblies 41 includes a series of nozzles 42, mounted and oriented at known or registered positions corresponding to the known, indexed positions of the castings being passed therethrough in their saddles. The number of nozzles in each nozzle station is variable, depending upon the core prints of the castings, such that different types of castings having differing core prints can utilize an optionally different arrangement or number of nozzles per nozzle station. The nozzles typically are controlled through a control system that can be operated remotely so as to engage or disengage various ones of the nozzles at the different nozzle stations as needed, depending upon the design or core prints of the castings passing through the heat treatment station.

Each nozzle 42 generally is mounted in a predetermined position and/or orientation, aligned with one of the core apertures or access openings or core prints or a set of core apertures formed in the castings according to the known, indexed positions or orientations of the castings within the saddles. Each of the nozzles is supplied with a high pressure heated fluid, typically including air, thermal oils, salt, water or other known fluids that are directed at the core openings under high pressure, typically approximately 1,000 FPM to approximately 15,000 FPM, although greater or lesser pressures also can be used

as required for the particular casting application. The pressurized fluid flows or blasts applied the castings by the nozzles tend to impact or contact the sand cores within the castings to cause the binder materials of the sand cores to at least partially degrade or break down. As the sand cores are broken down or dispersed by the fluid flows, the sand of the sand cores tends to be removed or cleaned from the castings through the core apertures or access openings with the passage of the fluid flows through the castings for recovery and reclamation of the sand.

The nozzles 42 of each nozzle assembly or station 41, further can be adjusted to different nozzle positions depending upon the characteristics of the castings and the pressure of the fluid flows or blasts can also be adjusted. The adjustment of the nozzles can be accomplished remotely, such as through the use of robotically movable or positionable nozzles. The fluids from the nozzles also can be applied at different temperatures, depending upon which zones within the heat treatment station of the nozzles from which they are dispensed are located, so that the fluid flows will not interfere negatively with the heat treatment process for the castings as they are moved through the heat treatment furnace or station. In addition, the nozzles of each nozzle station can be moved between various nozzle positions including moving between a rest position into an application position, or between several application positions, oriented toward the core apertures or access openings upon movement of the castings into each different zones or stations within the heat treatment station so as to strategically direct a high pressure flow of a heated fluid toward different core apertures or access openings to cause the sand cores to be broken up and dislodged from the castings

for removal of the sand cores therefrom. Thus, the use of the nozzle stations within the heat treatment furnace or station enhances and enables a more efficient breakdown and removal of the sand cores from each casting during heat treatment of the castings, and can assist in the reclamation of the sand materials from the sand cores for reuse.

As indicated in Fig. 1, after the heat treatment and core removal for each casting has been completed, each casting is removed from the heat treatment station 40 and typically is moved into a quenching station 45. The quenching station 45 typically includes a quench tank filled with a cooling fluid, such as water or other known material in which each casting is immersed for cooling and quenching. The capacity and size of the quench tank generally is a function of the castings being formed and the specific heat of the metal or metal alloy comprising the castings and the temperatures to which each casting has been heated. Alternatively, the quenching station can include a series of air nozzles for applying cooled air to the castings for quenching.

An additional embodiment of the present invention illustrating the in-die heat treatment of castings is illustrated in Figs. 4 – 8B. As illustrated in Fig. 4, in this embodiment of a casting process 50, a molten metal or alloy M is poured into a die 51 at a pouring or casting station 52. As indicated in Figs. 4 – 5B, the dies, 51 in this embodiment typically include flask type molds formed from a metal such as cast iron or similar material or can be green sand type molds formed from a sand material mixed with an organic binder as is known in the art, and generally include an internal chamber in which the castings 53 (Fig. 6 – 8B) are formed.

Each of the dies 51 further generally includes a sand core 54, as illustrated in Fig. 7, generally formed from a sand material mixed with an organic binder for forming bores and or core apertures or access openings in the castings formed within the dies and for creating casting details or core prints. The dies 51 in this embodiment, further typically include ports or die access openings 56 (Fig. 4 – 5B) that are formed at selected, desired positions or locations about the dies and extend through the side walls of 57 of the dies 51 so as to provide access to the castings 53 being formed within the dies (Figs. 6 – 8B) for direct application of heat to the castings while in-die and for dislodging and removal of the sand cores therefrom.

A heating element such as a heated air blower or other suitable gas or electric fired heater mechanism 58 (Fig. 4) also can be provided adjacent the pouring or casting station 52 for preheating the dies as the molten material M is introduced therein. Alternatively, the dies can be formed with cavities adjacent the castings within the dies, in which a heated gas, thermal oil or other heated medium can be received for preheating the dies and further heating the castings within the dies. Typically, the dies are preheated to a desired temperature depending upon the heat treatment temperature required for the metal or alloy being used to form the casting, i.e., 400 - 600°C for aluminum. The pre-heating of the dies tends to substantially maintain and minimize loss of the temperature of the castings being formed within the dies at or near the heat treatment temperature for the castings as the dies are transferred from the pouring station and to at least partially heat treat the castings as they solidify, and to enhance the heat treatment

of the castings by reducing heat treatment times since the castings do not have to be significantly reheated to raise their temperature to levels necessary for heat treatment.

Thereafter, once each die 51 has been filled with a molten material M, the die typically is transferred from the casting or pouring station 52 by a die transfer mechanism 59 into a loading station 61. The die transfer mechanism 59 generally can include a die transfer robot, winch, conveyor or other type of conventionally known transfer mechanism for moving the dies from the pouring station to the loading station. The transfer mechanism positions each die in a known, indexed position at the loading station, with the x, y and z coordinates of the dies being located in a known orientation or alignment prior for heat treatment.

In the present embodiment of the invention, the dies thereafter generally are moved into and through a heat treatment station 62 to at least partially heat treat the castings and break down their sand cores for removal. As discussed above, the heat treatment station 62 generally includes a heat treatment furnace, typically a gas fired furnace, having a series of treatment zones or chambers for applying heat to the dies for at least partial heat treatment of the castings "in-die". The number of treatment zones or chambers can be divided into as many or as few zones as an individual application may require, depending upon the castings being processed. Additionally, following at least partial heat treatment of the castings while in-die, the castings can be removed from their dies and passed through the heat treatment station for continued heat treatment, sand core removal and possibly for sand reclamation.

An example of a heat treatment furnace for the heat treatment and at least partial breakdown and/or removal of the sand cores from the castings while the castings remain "in-die", or the continued heat treatment, sand core removal, and possibly reclamation of the sand of the cores, from the castings after removal from their dies, is illustrated in U.S. Pat. Nos. 5,294,994; 5,565,046; and 5,738,162, the disclosures of which are hereby incorporated by reference. A further example of a heat treatment furnace for use with the present invention is illustrated and disclosed in U.S. Patent Application serial no. 09/313,111, filed May 17, 1999, the disclosure of which is likewise incorporated herein by reference. These heat treatment furnaces further enable the reclamation of sand from the sand cores of the castings that are dislodged through the die access openings during heat treatment of the castings while they remain in their dies.

As illustrated in Figs. 4 – 5B, the heat treatment station 62 further generally includes a series of nozzle stations 63 or assemblies each equipped with a plurality of nozzles 64. The nozzles of each of the nozzle stations generally are oriented at known, preset positions and/or orientations in registration with the known positions of certain ones or sets of die access openings 56 of the dies 51. The number of nozzle stations and the number of nozzles at each station can be varied as needed for providing heat in varying degrees and/or amounts to the dies for heat treating the castings therewithin to enable control of the heating of the dies and thus the castings, and the adjustment of the heating to different stages of heat treatment of the castings.

Each of the nozzles generally supplies a fluid flow or blast of a heated fluid that is directed toward the dies and typically toward a specific die access opening or set of die access openings of each die as indicated in Figs. 5A and 5B. The fluid medium applied to the dies typically includes water, air, thermal oils, salt or other conventionally known fluids that are supplied under high pressure and at varying temperatures to heat the dies, with the temperature of the fluid flows supplied by the needles being controlled to conform to different heat treatment stages as the casting is passed through the different nozzle stations of the heat treatment station. The introduction of the heated fluids into the dies through the die access openings further generally tends to cause a breakdown of the binder for the sand cores of the castings so as to cause the sand cores to at least partially degrade and be dislodged and/or removed from the castings during heat treatment, with the dislodged sand material passing through the die access openings with the draining of the fluids therefrom. In addition, the dies also potentially can be at least partially opened as they pass through the nozzle stations for more direct application of the heated fluids to the castings and core openings thereof for heat treatment and sand core removal.

In addition to having the castings pass through a series of nozzle stations that include nozzles mounted in fixed positions in registration or corresponding to the known positions of the dies, and thus the known positions of the die access openings, it is further possible to maintain the dies in a fixed casting position at a single nozzle station or at the pouring station for application of heated fluids thereto. In such an embodiment, nozzles 64' (Figs. 5A and 5B) typically are

robotically operated so as to be movable between a series of predetermined fluid application or nozzle positions as illustrated by arrows 66 and 67 in Figs. 5A and 5B. As the nozzles 64' move about the dies in the direction of arrows 66 and 67, they apply a heated, pressurized fluid media F against the dies, typically directed toward and into the access openings 56, so as to raise and maintain the temperature of the dies at a sufficient temperature for heat treating the metal casting therewithin as the molten metal of the castings is solidified. The various application or nozzle positions of the movable nozzles generally are determined or set according to the known x, y and z coordinates of the dies, and thus their die access openings, at the pouring station or upon the positioning or locating of the dies at the loading station by the die transfer mechanism.

The dies 51 of the present invention typically have the ability to be heated up to approximately 450 - 650°C or greater depending upon the solution heat treatment temperatures required for the alloy or metal of the casting that is required, and typically are preheated to a temperature sufficient to enable at least partial heat treatment of the casting during pouring of the molten metal. The heating of the dies further is controlled through control of the temperature of the fluid media applied to the dies so as to heat and maintain the dies at the desired temperatures needed for heat treating the metal of the castings being formed therein to minimize heat loss during transfer to the heat treatment station and thus minimize the amount of reheating required to raise the castings back to their heat treatment temperatures.

In alternate embodiments of the heat treatment stations shown in Figs. 6 - 8B, the nozzle stations can be supplemented or replaced with additional heat treatment chambers in which energy is supplied or directed toward the dies for raising and maintaining the temperature of the dies at the required temperature for heat treating the castings therein. In a first example of a heat treatment chamber 70, illustrated in Fig. 6, the dies or sand mold packs 51 generally are placed on a conveyor or transport mechanism 71 for movement through the heating chamber 70 as indicated by arrows 72. The heating chamber 70 typically is an elongated furnace chamber having an insulated floor, sides, and ceiling and, as illustrated in the embodiment of Fig. 6, includes a radiant energy source 73. The radiant energy source 73 typically is mounted in the ceiling of the heating chamber 70, although it will be understood by those skilled in the art that the radiant energy source can also be mounted in side walls, and that multiple radiant energy sources can be used, mounted in the side walls, overhead and/or below the dies as they are moved through the heating chamber 70 on the conveyor or transport mechanism. Typically, the radiant energy source will be a infrared emitter or other known type of radiant energy source.

The radiant energy source generally will direct radiant energy at approximately 400 - 650°C toward the dies passing through the heating chamber, typically being directed against the sides and/or top of each die as illustrated by arrows 74. The dies, and thus the castings therewithin, are subjected to the radiant energy source for a desired length of time, depending upon the metal of the castings being heat treated. The radiant energy generally is absorbed by the dies,

causing the temperature of the dies to correspondingly increase so as to heat the dies and thus the castings there within from the inside out.

Fig. 7 shows a further alternative heating chamber 80 for use in the in-die heat treatment of the present invention. As shown in Fig. 7, the heating chamber 80 generally is an elongated furnace having an insulated floor, ceiling and side and includes a conveyor or other transport mechanism 84 for moving the dies, with their castings therewithin, through the heating chamber 80 in the direction of arrows 82. The heating chamber 80 further includes an induction energy source 83 for applying induction energy to the dies or mold packs, and thus to the castings and sand cores 53 and 54 contained therewithin. The induction energy source generally can include a conduction coil, microwave energy source or other known induction energy sources or generators, and, as with the radiant energy source of Fig. 6, can be positioned in the ceiling of the heating chamber 80, above the dies, along the sides of the heating chamber, or both. The induction energy source will create a high energy field of waves, indicated by arrows 84, that are directed toward the top and/or sides of the dies 51 and are of a particular frequency or frequencies that will be absorbed by the sand cores 54 so as to cause the temperature of the sand cores and thus the castings to be increased to correspondingly heat treat the metal castings within the mold packs by heating the casting and thus the dies from the inside out.

Still a further alternative construction of a heating chamber 90 for use in the present invention for heat treatment of the castings while "in-die" by adding energy to the dies and thus the castings to increase the temperature thereof is

shown in Figs 8A and 8B. In this embodiment, the dies typically will comprise sand mold pack type dies, although flask type molds also could be used. As shown in Figs. 8A and 8B, the heating chamber 90 typically is an elongated furnace chamber that includes a conveyor or transport mechanism 91 for conveying the dies 51 with their castings 53 contained therein in the direction of arrows 92. As the dies and castings are moved through the heating chamber 90, they are passed through a low velocity oxygen chamber 93. The oxygen chamber generally includes a high pressure, upstream side 94 and a low pressure, downstream side 96 that are positioned opposite each other to assist in the drawing of the oxygen flow through the dies. As indicated by arrows 97 (Fig. 8A) and 97' (Fig. 8B), as the dies pass through the low velocity oxygen chambers of the heating chambers 90 heated oxygen gas is directed at and is forced through the dies or mold packs. As the oxygen gas is drawn or flows from the high atmospheric pressure side to the low atmospheric pressure side, of the oxygen chamber, flowing through the dies or mold packs, a percentage of oxygen is combusted with the binder material of the sand mold packs and sand cores, so as to enhance the combustion of the binder material within the heating chamber. As a result, the mold packs and their castings are further supplied with energy from the enhanced combustion of the binder material thereof and the oxygen, which thus increases the temperature of the castings in the mold packs, while at the same type breaking down the binder of the mold packs and sand cores for ease of removal and reclamation. As shown in Figs. 8A and 8B, the low velocity oxygen chamber can be oriented in either a vertical orientation (shown in Fig. 8A) or a

substantially horizontal orientation (shown in Fig. 8B) for forcing the hot oxygen gasses through the mold packs, depending upon size and space configurations for the heating chamber.

Further, it is also possible to carryout the increasing of the temperature of the dies or sand mold packs for in-die heat treatment of the castings, while reducing the potential heat loss transfer between the molten material and die surfaces, and the atmosphere, by including an energy source within the die itself. In such an embodiment, the dies typically are formed with cavities or chambers in close proximity to the internal cavity in which the casting is formed. A heated fluid media, such as thermal oils, water, or similar or other material capable of readily retaining heat is then be supplied to the die structure being received within these cavities. This heated fluid tends to increase and help maintain the temperature of the casting at a desired level needed for heat treatment.

As a result of applying energy to the die or mold packs themselves, the dies are heated to desired temperatures and can be maintained at a such temperatures as needed for heat treating the castings being formed therewithin as the molten metal of the casting is solidified within the dies. Such in-die heat treatment of the castings can significantly cut the processing time required for heat treating castings, for example, from approximately 250 minutes to as low as approximately 50 minutes, as the metal of the castings is generally elevated and stabilized at the heat treatment temperature shortly after pouring of the molten metal material into the dies, so that heat treatment of the castings can take place in a relatively short period of time following the pouring of the molten metal

material into the dies. The raising of the temperature of the dies to the heat treatment temperature for heat treating the castings, further enhances the breakdown and combustion of the combustible organic binders of the sand cores and/or sand molds, if used, so as to further reduce the time required for the heat treatment and dislodging and reclamation of the sand cores and sand molds of the casting process.

Following the heat treatment of the castings in their dies within the heat treatment station 62, the castings typically are removed from their dies and can be moved to an additional heat treatment station for completion of the heat treatment of the castings, as needed, and for sand core removal and possible reclamation of the sand materials of the cores. The castings are then moved into a quenching station 100 for quenching and cooling of the castings. Alternatively, as shown in Fig. 4, the castings can be removed from their dies and transferred directly to the quenching station. The quenching station 100 typically includes a quench tank having a cooling fluid such as water or other known coolant material, but the quenching station can also comprise a chamber having a series of nozzles, indicated at 101 in Fig. 4, that apply cooling fluids such as air or water to the castings. The quenching also can take place in contiguous ancillary quenching equipment that is in close proximity to the pouring station so that cycle time and heat variations can be minimized for the setting and treatment of the molten metal material of the casting within the dies.

After heat treatment and sand removal of the castings is completed, the castings can be removed from the dies and then immersed in the quench tank of

the quench station for cooling the castings before further processing, and sand removed from the castings then can be reclaimed for later reuse. In addition, as indicated in dashed lines in Fig. 4, it is also possible to transfer the dies directly from the pouring station to the quenching station. For example, where the dies from the pouring station are heated to a heat treatment temperature at or adjacent the pouring station for heat treating the castings, the dies can then be transferred directly to the quenching station.

Accordingly, the present invention enables the reduction or elimination of a requirement for further heat treating of the castings once removed from the dies, which are heated to provide solution heating time and cooled to provide the quenching effect necessary, while in-die, so as to significantly reduce the amount of heat treatment/processing time required for forming metal castings. The present invention further enables an enhanced or more efficient heat treatment and breakdown and removal of sand cores within the castings by directing fluid flows at the castings at preset positions, corresponding to known orientations or alignments of the castings and/or the dies with the castings contained therein as they are passed through a heat treatment station.

It will be understood by those skilled in the art that while the present invention has been discussed above with reference to preferred embodiments, various additions, modifications and changes can be made thereto without departing from the spirit and scope of the invention as set forth in the following claims.

## Claims

1. A method of processing a casting of known metal, comprising:

pouring a metal in molten form into the die;

retaining the metal within the die for a time sufficient to at least partially solidify the metal so as to form a casting having a core and core openings therein;

placing the casting in an indexed position so that at least a plurality of the core openings are oriented in a known position aligned with a plurality of nozzles; and

directing a fluid flow from the nozzles at and into the core openings to dislodge the cores from the castings..

2. The method of claim 1 and further comprising the steps of:

aligning at least a plurality of the core openings and a second plurality of nozzles; and

directing a fluid from the second plurality of nozzles at and into the core access openings.

3. The method of claim 1 and further comprising removing the casting from the die prior to placing the casting in its indexed position.

4. The method of claim 3 and wherein placing the casting in an indexed position comprises positioning the casting at a first position with the x, y

and z axes of the casting oriented in a known first orientation, and wherein the at least a plurality of core openings are in alignment with the plurality of nozzles.

5. The method of claim 1 and further comprising:

removing the casting from the die prior to placing the casting in its indexed position;

placing the casting at a first position with the x, y and z axes of the casting oriented in a known first orientation, so that at least a plurality of core openings are in alignment with a first plurality of nozzles;

directing a fluid flow from the first plurality of nozzles into the core openings;

placing the casting at a second position with the x, y and z axes of the casting oriented in a known, second orientation, different from the first orientation so that at least a plurality of core openings are in alignment with a second plurality of nozzles; and

directing a fluid flow from the second plurality of nozzles at the core openings.

6. The method of claim 1and further comprising:

placing the casting in a first casting position with the x, y and z axes of the casting oriented in a known orientation;

moving the plurality of nozzles to a first nozzle position in alignment with at least a plurality of core access openings; and

moving at least a portion of the plurality of nozzles to a second nozzle position, wherein the portion of the plurality of nozzles is in alignment with at least a second plurality of core openings.

7. The method of claim 1 and further comprising:

transferring the casting from the die to a saddle; and

positioning the casting on the saddle such that the x, y and z coordinates of the casting are known.

8. A method of processing a metal casting, comprising:

providing a die with a casting core;

pre-heating the die to a temperature sufficient to at least partially heat treat the metal of the casting;

pouring a metal, in molten form, into the die;

at least partially heat treating the metal in the die to form a casting having a core casting therein defining core openings in the metal casting; and

removing the core from the casting.

9. The method of claim 8 and further comprising:

aligning a plurality of the core openings with a first plurality of nozzles; and

directing a fluid flow from the first plurality of nozzles toward the core openings.

10. The method of claim 9 and further comprising:

aligning a plurality of the core openings with a second plurality of nozzles; and

directing a fluid flow from the second plurality of nozzles toward the core openings.

11. The method of claim 9, wherein aligning the core access openings with a first plurality of nozzles comprises positioning the casting at a first position with the x, y and z coordinates of the casting in a known first orientation and wherein at least a plurality of core openings are in alignment with a first plurality of nozzles.

12. The method of claim 9 and further comprising:

removing the casting from the die;

positioning the casting at a first position so that x, y and z axes of the casting oriented in a known first orientation with at

least a plurality of core openings in alignment with a first plurality of nozzles;

applying a fluid to the casting with the first plurality of nozzles to at least partially dislodge the core from the casting;

positioning the casting at a second position with the x, y and z axes of the casting oriented in a known second orientation, different from said first orientation and with at least a plurality of core openings in alignment with a second plurality of nozzles; and

applying a fluid to the casting with the second plurality of nozzles.

13. The method of claim 8, and wherein at least partially heat treating the casting comprises:

maintaining the die and casting at a known position;

moving a plurality of nozzles to a first nozzle position about the die;

applying a heat to the die with the nozzles to at least partially dislodge the core from the casting;

moving at least a portion of the plurality of nozzles to a second nozzle position; and

further applying heat to the die with the nozzles in their second nozzle position to further heat treat the casting within the die.

14. The method of claim 8 and wherein the metal includes aluminum and the pre-heating step comprises pre-heating the die to a temperature in the range of 400-600 °C.

15. The method of claim 8 and further comprising maintaining the temperature of the die in a range sufficient to at least partially heat treat the metal of the casting for a period of time sufficient to complete the heat treatment of the metal of the casting.

16. The method of claim 8 and further comprising moving the casting through a plurality of nozzle stations, wherein each station is equipped with a plurality of nozzles.

17. The method of claim 8 and wherein the casting core is formed from sand, and further comprising reclaiming the sand of the core with the removal of the core from the casting.

18. The method of claim 8 and further comprising quenching the casting.

19. A system for manufacturing castings from molten metals comprising:

a series of dies in which molten metal is received to define and form the castings;

a series of saddles adapted to receive the castings in a desired orientation having known, indexed position coordinates; and

a heat treatment station in which the saddles, with the castings located in their known, indexed position therein, are received for heat treatment of the castings and core removal, wherein said heat treatment station includes:

a plurality of nozzle stations, each equipped with a plurality of nozzles arranged in alignment with the known position coordinates of the castings for applying a fluid flow to the castings to substantially dislodge the cores from the castings.

20. The system of claim 20 and wherein said nozzle stations each comprise a series of robotically operated nozzles adapted to move about the castings between at least first and second nozzle positions for directing fluid flows toward the castings from different directions to substantially dislodge and remove the cores from the castings.

21. The system of claim 20 and wherein said saddles each include a series of walls defining a casting receptacle and a plurality of locating devices positioned within said casting receptacle, so as to engage and guide the

castings into their known, indexed positions having known position coordinates within said saddles.

22. The system of claim 22 and wherein said locating devices comprise guide pins and wherein the castings are formed in said dies with corresponding locating openings in which said guide pins are received for locating the castings in their known, indexed positions within said saddles.

23. The system of claim 20 and wherein said dies comprise flask type molds having a heating source for preheating said dies and at least partially heat treating the castings.

24. The system of claim 20 and further comprising a quenching station for quenching the castings.

25. A system for manufacturing of metal castings, comprising:

a die in which a metal material is received for forming the casting;

a heat treatment station including a heat treatment chamber in which said dies are subjected to application of heat for at least partially heat treating the castings within said dies; and

wherein said heat treatment station includes a means for heating said dies to a temperature sufficient to at least partially heat treat the castings therewithin.

26. The system of claim 25and wherein said means for heating comprises at least one nozzle station positioned along said heat treatment station and having at least one nozzle initially mounted in alignment with a series of die access openings formed in said die for applying a fluid media to said die for heating said die and dislodging core material of a core within the casting.

27. The system of claim 25 and wherein said means for heating comprises a radiant energy source mounted in said heating chamber so as to direct radiant energy toward said die.

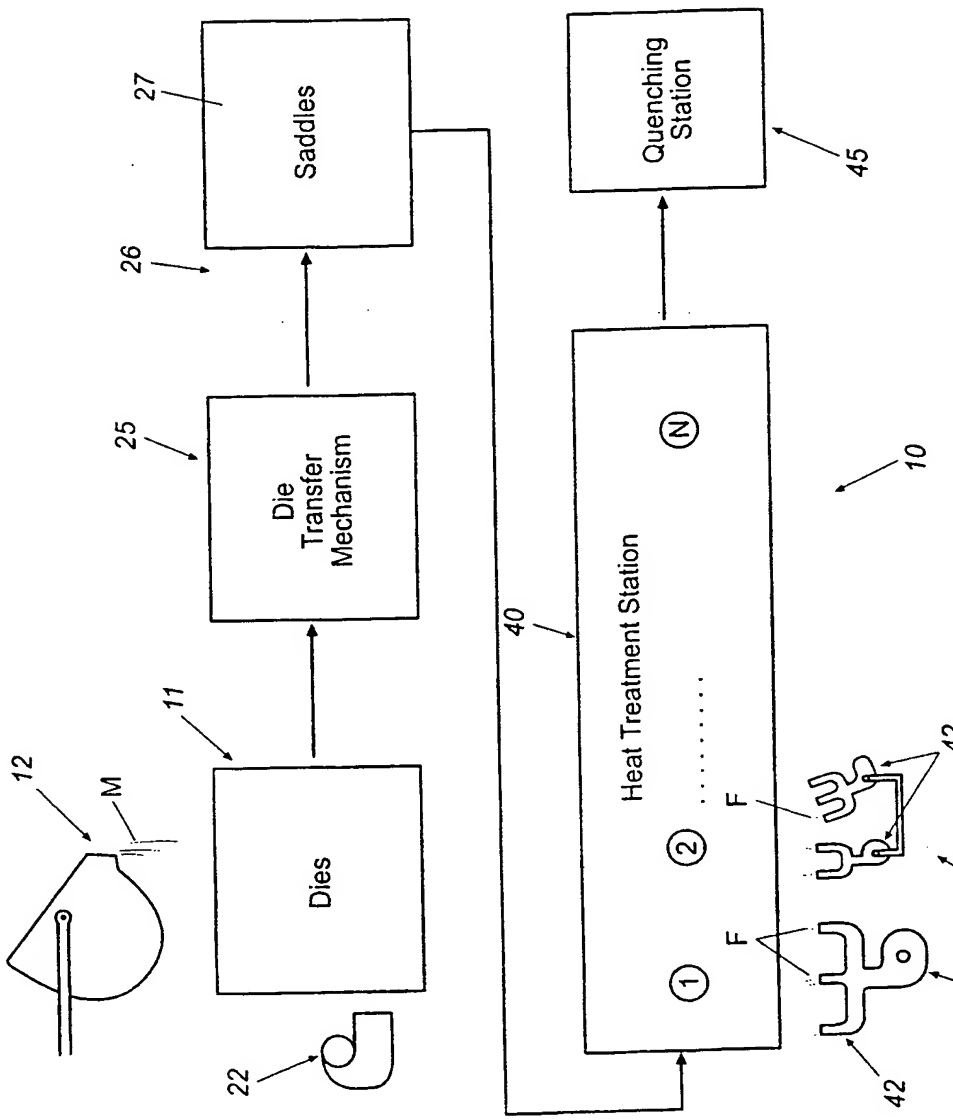
28. The system of claim 25 and wherein said means for heating comprises an induction energy source mounted within said heating chamber for transmitting inductive energy to said die.

29. The system of claim 25 and wherein said means for heating comprises an oxygen chamber positioned along said heat treatment station for directing a flow of oxygen through said dies for reacting and combusting with a

binder material, in order to increase the temperature of the castings within said dies.

30. The system of claim 26 and further wherein said means for heating further includes an energy source positioned in said heating chamber for applying energy to said die to heat said die from inside out.

31. The system of claim 25 and further comprising a quenching station for quenching the heat treated castings.


Saddles
Die Transfer Mechanism
Dies
Quenching Station
Heat Treatment Station
1
2
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F
F
M
10
11
12
22
25
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41
42
42
45

Fig. 1

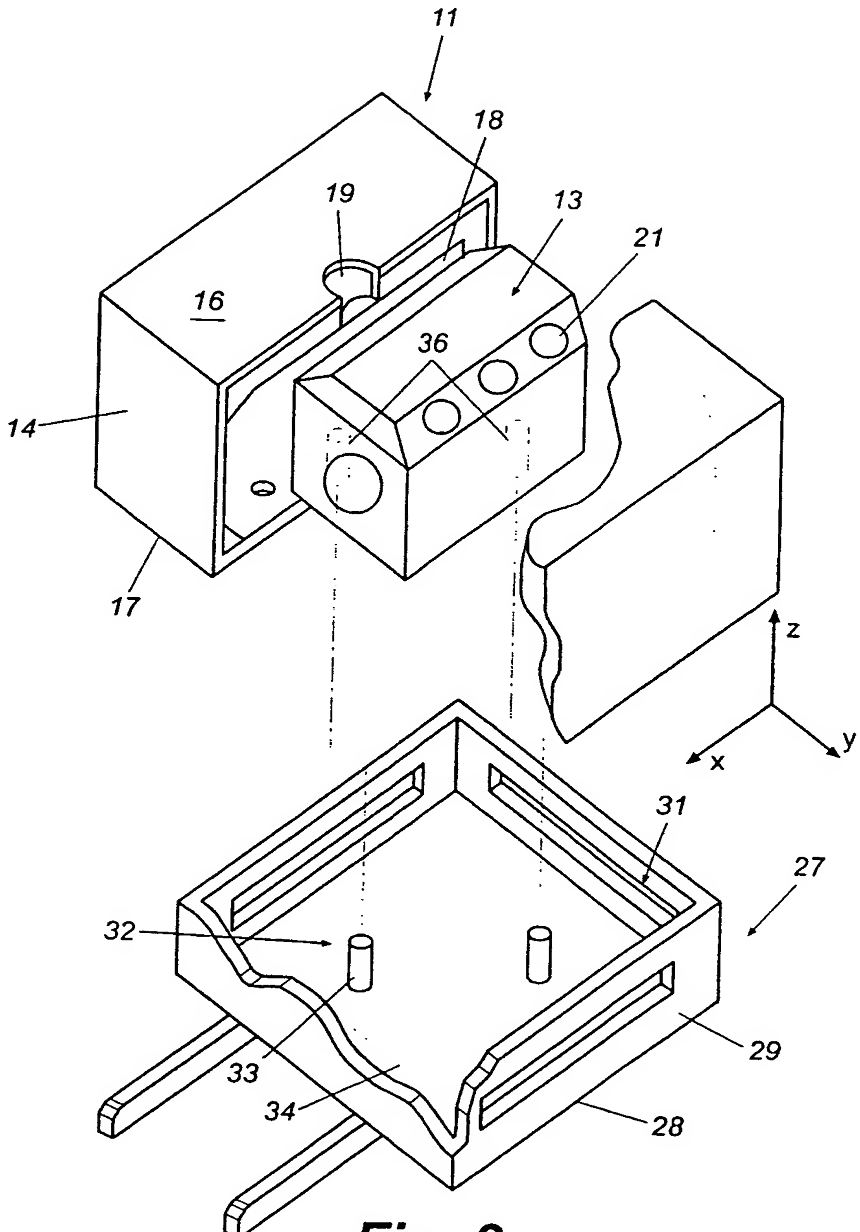
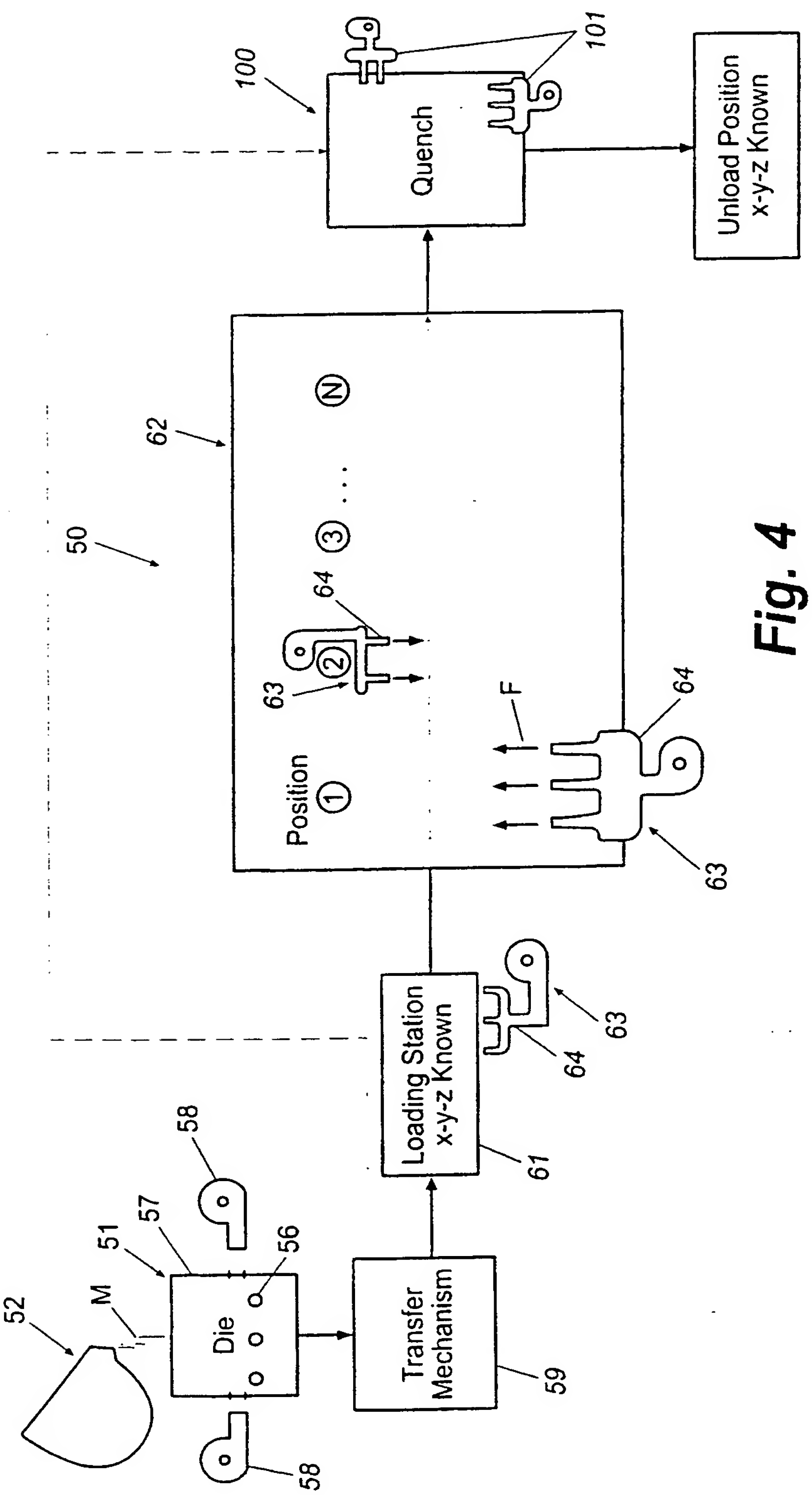



Fig. 3



100
101
Quench
Unload Position
x-y-z Known
62
50
Position ①
②
③ . . .
Ⓝ
63
64
F
Loading Station
x-y-z Known
61
52
M
51
57
58
56
Die
Transfer
Mechanism
59


Fig. 4

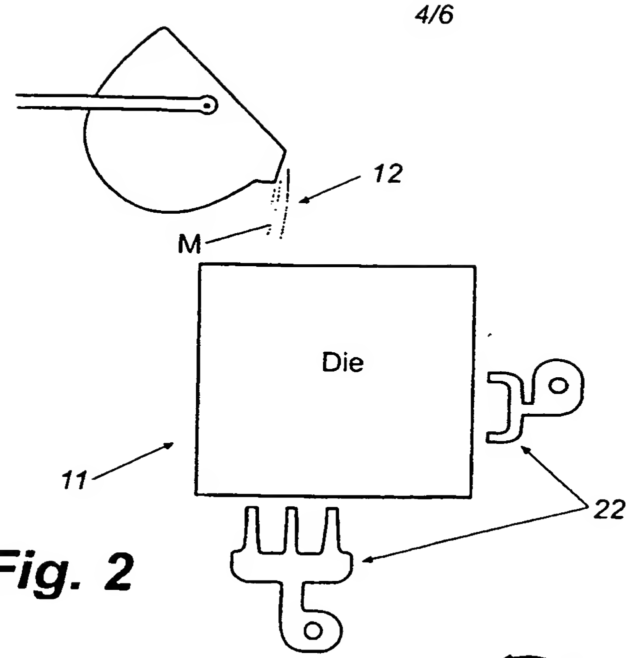



Fig. 2

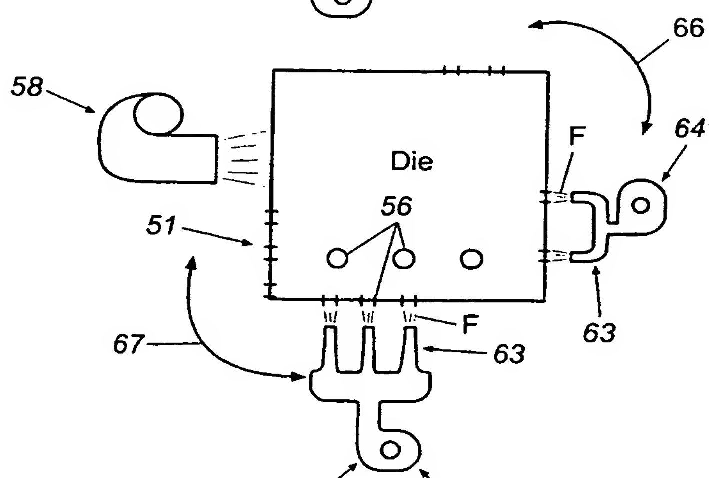



Fig. 5A

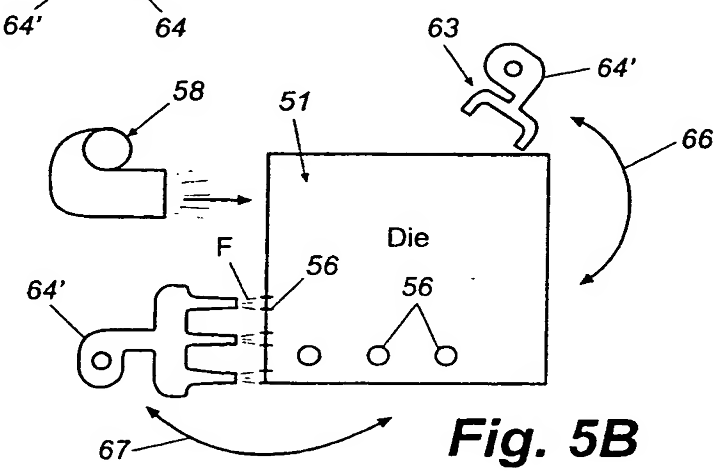
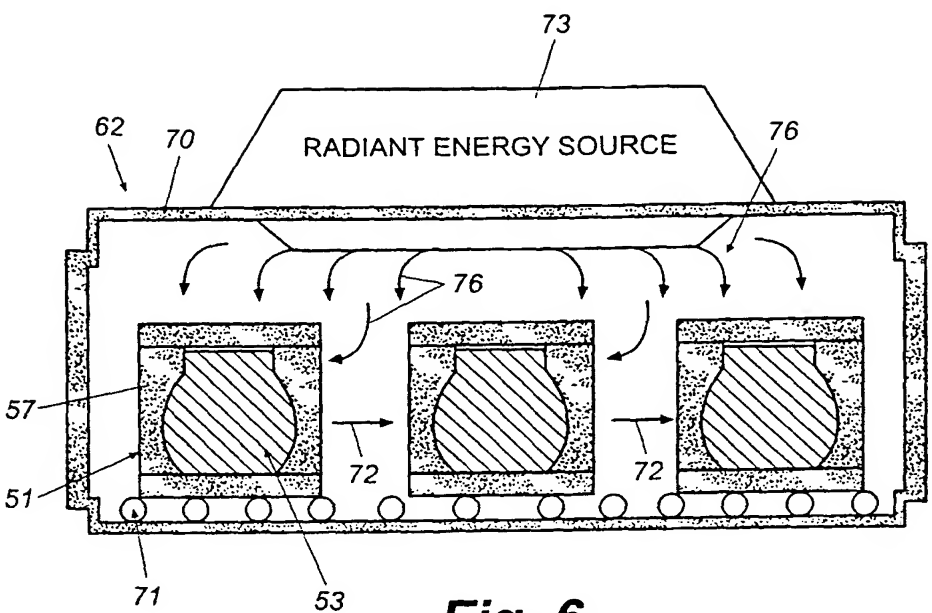



Fig. 5B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53

Fig. 6

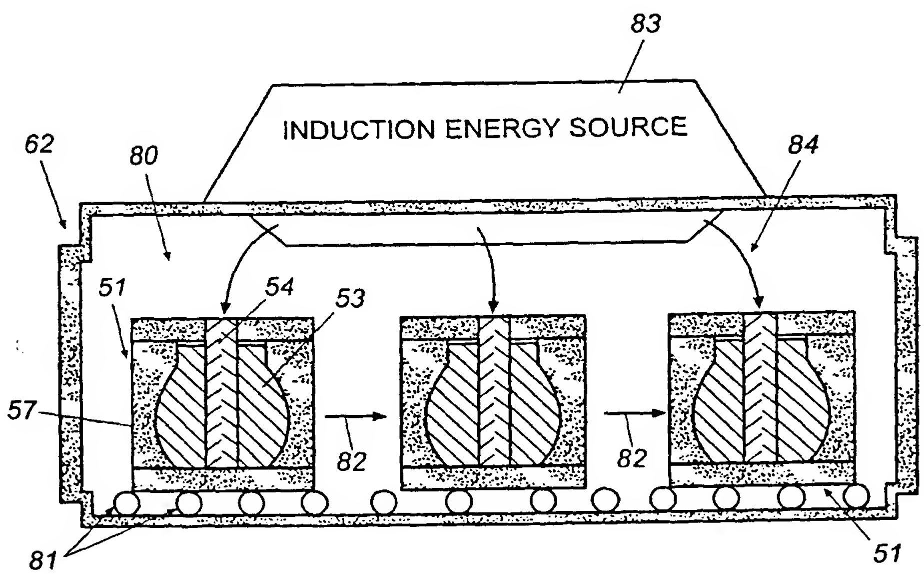
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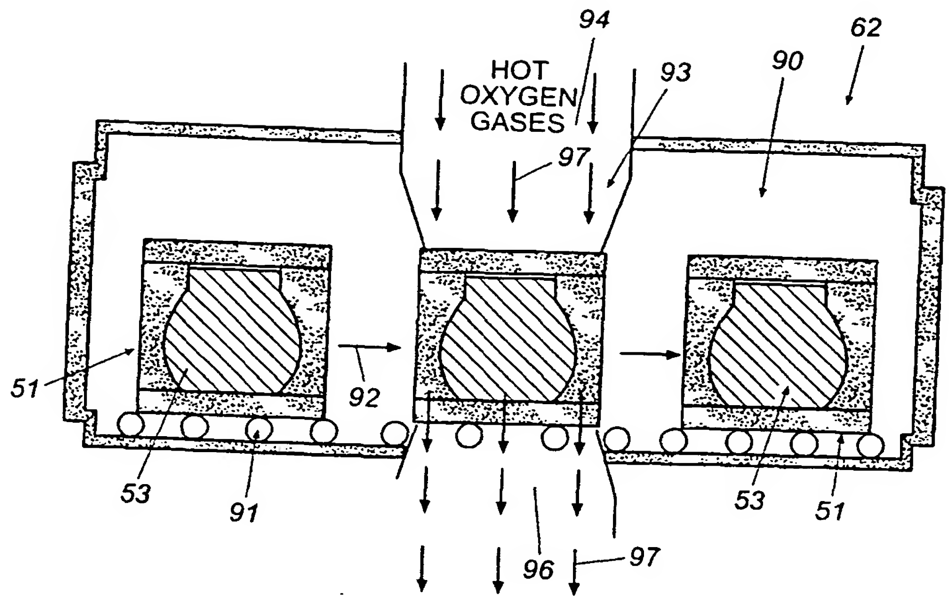
Fig. 7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OXYGEN
GASES
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92
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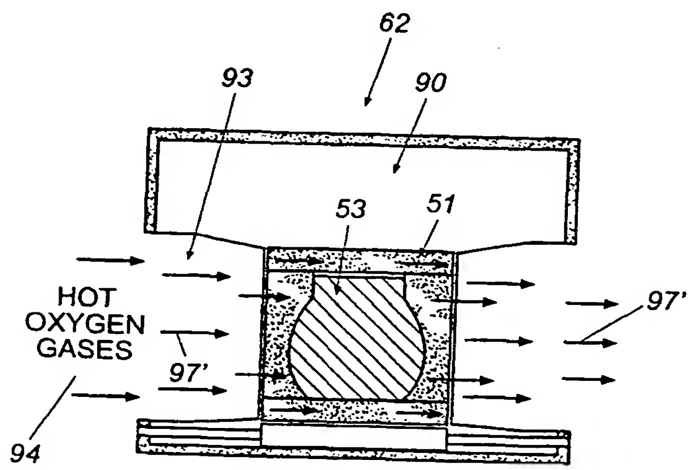
91
53
51
96
97

Fig. 8A


62
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90
53
51
HOT
OXYGEN
GASES
97'
97'
94

Fig. 8B

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/US00/20466

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) :B22D 29/00; C21D 1/00
US CL :164/5, 132, 76.1
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 164/5, 132, 76.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WEST

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 5,294,094 A (CRAFTON et al) 15 March 1994, col. 4, lines 4-35 and figures 1-3. | 1-31 |
| Y | US 4,499,940 A (HALL) 19, February 1985, col. 2, lines 45-48. | 8-18, 23 |
| Y | JP 1-91,957 A ( SASAKI et al) 11 April 1989, abstract. | 1-7, 9-13, 16, 19-31 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 11 OCTOBER 2000 | 14 NOV 2000 |

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